PROCESSING OF KARIN/SWOT DATA

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1. INTRODUCTION

The Surface Water and Ocean Topography (SWOT) mission [1] is part of NASA's Decadal Survey Program, and prepared jointly by NASA's Jet Propulsion Laboratory (JPL), the French space agency (CNES), and the Canadian space agency (CSA). Launch is currently foreseen in 2020.

The principal instrument KaRIn (Ka-band Radar Interferometer) would be a bistatic SAR system operating at Ka-band, with 200 MHz bandwidth, covering 50 km wide near-nadir swaths (1-4° incidence) on both sides of the satellite track [2]. The nominal payload also would include a conventional Ku/C-band nadir altimeter, a water vapor radiometer, and a precise orbit determination suite. Moreover, additional near-nadir channels from KaRIn to reduce the gap between the nominal swaths may be considered.

The main mission goals [3] would be to improve the spatio-temporal coverage of the oceans with respect to today's nadir-looking altimeters (such as the Jason series), by providing measurements on a 1 km^2 grid with virtually complete coverage up to ±78° latitude, while keeping a height precision of 1-2 cm, and to extend the altimetry measurements to continental water surfaces, including lakes, reservoirs and wetlands bigger than 250×250 m^2 and rivers down to a width of 100 m (50 m as a goal), with a height precision of the order of 10 cm, represented with a horizontal point spacing of about 50 m.

The fine scale of the measurements, with continuous acquisition over both oceans and continents, will result in huge data volumes, starting at the spacecraft and flowing through all links of the ground system. Furthermore, the centimetric height accuracy required means that all aspects of the processing must be considered carefully.

In this article we give an overview of the foreseen data products and data processing chains for KaRIn on SWOT. Some particularly challenging processing steps are (will be) described in more detail.

2. DATA PROCESSING OVERVIEW

In terms of transmission and reception, KaRIn works is the same bistatic mode over both oceans and continents. In terms of processing and data products, however, KaRIn features a low resolution (LR) mode dedicated to oceanography and a high resolution (HR) mode dedicated mainly to continental hydrology. For both modes, the processing steps can roughly be divided into the following main categories:

1. SAR processing (range and azimuth compression)
2. Interferometric processing (computation of interferometric phase and coherence)
3. Restitution of acquisition geometry (geolocation, precise orbit determination, correction of roll, baseline variations, tropospheric delay, …)
4. Extraction of geophysical parameters (HR water surface detection, computation of heights, slopes etc.)

In the LR mode (oceanography), a considerable part of the data processing is done onboard, including unfocussed SAR processing and computation of 9 squinted and spatially averaged to about 1 km^2 pixels. These operations reduce the data rate considerably, from more than 1 Gbps to less than 3 Mbps, with a negligible loss of height precision compared to full SAR processing followed by spatial multilooking to the same resolution [4]. A requirement for the onboard processing is that KaRIn know the range to the sea surface to about 1 m.

The HR mode (hydrology) has very limited onboard processing, only presumming by a factor 2 in azimuth and BAQ coding, yielding a net instrument data rate of about 360 Mbps. The high data rate is necessary to preserve high spatial resolution (4 m $\times$ 10-70 m) in order to detect, localize, and characterize relatively small water surfaces. The final HR products will be represented as triangular irregular network with 50 m average spacing.

Flowcharts summarizing the currently proposed sequence of processing steps for the LR and HR KaRIn data will be presented. It should be noted that several strategies are possible concerning the order in which the processing steps are carried out and that there generally are several candidate algorithms for each processing step (e.g., many different algorithms for water surface detection in HR mode). Comprehensive prototyping and testing is therefore needed to establish the operational processing chains.

About 1 TB of data will be downlinked from SWOT every day, of which the raw (L0) KaRIn HR data represent about 99%. With the products computed in the ground segment, the mission will produce about 7 TB of data per day. A table summarizing the KaRIn data products will be presented.

KaRIn data will be processed on a swath basis as soon as precision orbit information and ancillary data are available (approximately 22 days, the orbit repeat cycle, in order to have crossover calibration data). The Geophysical Data Record (GDR, Level 2) for the ocean is a relatively straightforward extension to swath geometry of the traditional ocean altimeter (TOPEX, Jason) GDR. However, the hydrology data product poses unique challenges with its requirement for 50 m posting of water heights. It is not feasible to distribute this product as a raster, so it will be made as a triangular irregular network (TIN) with location, elevation, classification, associated metadata and errors in the estimates for areas within and near water detected in the SWOT swath. Approaches to providing additional easier-to-use information for hydrologists such as shapefile polygons for all lakes/reservoirs/wetlands, shapefiles for rivers with associated reach averaged discharge information based on Manning's equation, and floodplain geometry from the TIN, will be examined. All data products will be produced for each 22-day cycle, enabling the calculation of surface water storage change on monthly time scales.

3. PROCESSING CHALLENGES

While many steps of the KaRIn processing chains can be based on experience and methodology from nadir altimetry and interferometric missions such as SRTM, as well as airborne campaigns, some processing steps are specific to KaRIn or challenging due to the extremely high precision required and the particular characteristics of KaRIn. Some examples are given below (more detailed descriptions will be given in the final article/presentation).

3.1. Detection of continental water surfaces (HR)

The automatic detection of continental water surfaces in HR images is a crucial step because most of the subsequent processing is limited to the detected water surfaces (phase unwrapping, parameter extraction etc.). A variety of segmentation and classification methods exist, some able to precisely delineate relatively large water bodies [5], others specialized in the difficult task of detecting narrow structures such as rivers [6]. Such complementary methods as well as prior data could be combined through data fusion techniques to maximize the performance.

3.2. Prediction of land/water layover (HR)

Due to the near-nadir observation geometry, layover will occur very frequently in the KaRIn HR images, i.e., wherever the surface slope exceeds the incidence angle (1-4°). Contamination of water surfaces from surrounding land surfaces and vegetation due to layover could therefore be a considerable problem for the detection of water surfaces and the extraction of water surface height. The negative impact of layover is however limited by the fact that water/land contrast generally is very high, so that the backscattering from water will dominate [2, 7]. Moreover, if a sufficiently precise DEM is available, layover is easily predictable from a geometric point of view. The layover mask can be obtained by simulating reference interferograms with and without layover from the DEM. Considering the local water/land contrast, it is also possible to predict where the impact of layover on the interferometric phase is so strong that the pixels should be excluded from the water surface height estimation.

3.3. Phase to height conversion (HR and LR)

The phase to height conversion of the KaRIn data is somewhat different from what is usually done for DEM extraction over land. It is for example difficult to unwrap from precise reference points for water surfaces, due to the targeted height precision, the fact that water surface height is varying, and that it may be impossible to propagate from land reference points due to layover (land/water and land/land). The general approach for KaRIn is therefore to avoid spatial unwrapping through phase flattening based on a reference height map that must be within +/- half the altitude of ambiguity of the real height (the altitude of ambiguity varies from 10 m in near range to 60 m in far range). Algorithms for automatic detection and correction of cases where this requirement is not fulfilled will be developed.

3.4. Crossover calibration (HR and LR)

Absolute height calibration and correction of height errors in the swath due to roll and baseline variations will be based on orbit crossovers with SWOT and other altimeters. This will be presented in more detail in [8].

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